INVENTION DISCLOSURE

REDUCED HOPPING SEQUENCES (RHS) FOR BLUETOOTH

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I. INTRODUCTION

Bluetooth currently operates in the 2.4 GHz ISM band (2.400-2.4835 GHz) and hops over 79 frequencies in the United States. The FCC rules mandate that any system that operates under FCC regulation 15.247 must hop over at least 75 frequencies, and must use all the frequencies equally (i.e. the devices must spend the same average amount of time at each frequency). Since Bluetooth was designed to operate under 15.247, its hopping pattern is chosen so that approximately equal time is spent in each of the 79 frequencies. Problems with coexistence can arise when other devices share the ISM band such as IEEE 802.11b wireless local area networks (WLAN) or microwave ovens. Interferers which remain stationary in the ISM band will greatly reduce the throughput of Bluetooth piconets and/or increase the packet error rate (PER) whenever the Bluetooth devices hop into the interferers frequency bands. As an example, a Bluetooth piconet carrying a voice conversation generally needs a PER of less than 1%. If a microwave oven is operating near the Bluetooth piconet and occupies a bandwidth of 10 MHz with a 50% duty cycle, then on average 5 frequencies will be unusable to the Bluetooth piconet. The PER floor due to interference from the microwave oven will be 5/79 = 6%, which will result in poor voice quality.. This invention is a way to reduce the number of hopping frequencies so that interferers can be avoided.

II. PRIOR ART

No known prior art.

III. NEW INVENTION

The new invention is a method where the number of hopping frequencies that are used in a Bluetooth piconet is reduced. This allows stationary interferers (in frequency) such as IEEE 802.11b WLAN's or microwave ovens to be avoided so that the throughput and PER of Bluetooth piconets can be improved. In the preferred embodiment, the master determines which frequency bands contain a strong interferer. This determination can be made by a probing technique where the $E_b/(N_o+I_o)$ or the RSSI (received signal strength indicator) is measured for each channel. Alternatively, the master can simply monitor the PER on each frequency to find which frequencies have a large PER and should be avoided. Once the master determines the frequencies to avoid, the master can communicate this information to enhanced slaves that are capable of supporting reduced hopping sequences (RHS). The master can then communicate with the enhanced slaves using RHS, and the master can continue to communicate with normal Bluetooth slaves using the normal Bluetooth hopping sequence. One way of generating the RHS is illustrated in Figure 1. In Figure 1, ten frequencies of the normal hopping sequence are designated as f_0 to f_9. This figure simply illustrates a segment of the hopping sequence to show how the reduced hopping sequence is generated. In this example, let f_4, f_7, and f_8 be three frequencies in the set of frequencies to be avoided. These frequencies are not used in the RHS, and instead the previous available frequency in the sequence is substituted for these avoided frequencies. In Figure 1, the circles show which frequencies are changed in the RHS. Since f_4 is to be avoided, the previous frequency f_3 is used instead. Similarly f_7 and f_8 are to be avoided, so f_6 is used instead. One advantage of this method of generating the RHS is that all the remaining frequencies are used equally on average. Another advantage in that the difference in the normal hopping sequence and RHS is minimized, which makes it easier for a

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Exhibit C

master to support both normal and enhanced Bluetooth slaves. Other methods of forming the RHS can be used such as a modulo operation where frequencies that are to avoided are mapped into other frequencies.

Normal Hopping Sequence $f_0\ f_1\ f_2\ f_3\ f_4\ f_5\ f_6\ f_7\ f_8\ f_9$

Reduced Hopping Sequence $f_0\ f_1\ f_2\ f_3\ f_3\ f_5\ f_6\ f_6\ f_6\ f_9$

Time →

Figure 1: Comparison of normal hopping sequence and reduced hopping sequence.

Systems which use the RHS no longer qualify under FCC regulation 15.247, but they still qualify under 15.249. Under 15.249, devices are permitted to transmit an average power of (0.75 mW)(number of frequencies used for hopping with 1 MHz bandwidth). If the RHS uses 60 frequencies, then the devices can transmit 45 mW or 16.5 dBm. Most current Bluetooth devices are designed to transmit 0 dBm, and the cost of the Bluetooth devices will increase when the power output is over 10 dBm since an additional power amplifier is needed. Thus, the power restrictions under 15.249 should not be a significant limitation to enhanced Bluetooth devices.

There are several ways the master can choose the reduced hopping sequences. The master can decide individually whether or not to use each of the 79 frequencies. The master can then send a packet with 79 information bits which represent the 79 frequencies to indicate whether each one is used or not. Alternatively, the master can choose whether or not to use predetermined groups of frequencies. Since IEEE802.11b devices typically use one of three 22 MHz bands, the master can group frequencies according to the 802.11b frequency plan. If an 802.11b network is using one or more of these bands, the master can indicate to the enhanced slaves not to use the affected frequency groups. A frequency group for the microwave oven band can also be used. Using predetermined groupings will decrease the amount of information that the master needs to communicate to the enhanced slaves on which frequencies to avoid.

Alternative embodiments

1) Similar methods can also be used to reduce the number of frequencies used for the 23-hop sequences used in Spain, France, and Japan.

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